

AD-A278 241

493-10



USAEC Report No. SFIM-AEC-TS-CR-94021

Waste Reduction Technology Demonstrations

Summary

Submitted to:

**U.S. Army Environmental Center
(USAEC),
Aberdeen Proving Ground,
Maryland**

January 25, 1994

S DTIC ELECTED APR 06 1994 D

**Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390**

ADL Reference 43268

DACA31-93-P-0647

MANUFACTURED BY THE
WILLIAMSON COMPANY

94 4 5 083

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0186

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Analysis, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0186), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)			2. REPORT DATE January 25, 1994		3. REPORT TYPE AND DATES COVERED Final 4/93-1/94		
4. TITLE AND SUBTITLE Waste Reduction Technology Demonstrations Summary			5. FUNDING NUMBERS				
6. AUTHOR(S) J.L. Mahannah, A.A. Balasco							
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Arthur D. Little, Inc. Acorn Park Cambridge, MA 02140-2390			8. PERFORMING ORGANIZATION REPORT NUMBER 43268				
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Environmental Center ATTN: SFIM-AEC-TSD Aberdeen Proving Ground, MD 21010-5401			10. SPONSORING/MONITORING AGENCY REPORT NUMBER SFIM-AEC-TS-CR-94021				
11. SUPPLEMENTARY NOTES							
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unlimited			12b. DISTRIBUTION CODE				
13. ABSTRACT (Maximum 200 words) Since the early 1980s, the U.S. Army Environmental Center (formerly the U.S. Army Toxic and Hazardous Materials Agency) has had the responsibility for conducting demonstrations of technologies with the potential to reduce or eliminate the generation of hazardous wastes at Army industrial facilities. This report provides a summary of selected demonstrations as well as a matrix illustrating their status and applicability.							
DTIC QUALITY INSPECTED 3							
14. SUBJECT TERMS Hazardous wastes, Waste minimization, Army depots, Army ammunition-plants, Explosives, Electroplating			15. NUMBER OF PAGES 16		16. PRICE CODE		
17. SECURITY CLASSIFICATION OF REPORT Unclassified		18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified		19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified		20. LIMITATION OF ABSTRACT Unlimited	

Waste Reduction Technology Demonstrations

Since the early 1980s, the U.S. Army Environmental Center (formerly the U.S. Toxic and Hazardous Materials Agency) has had the responsibility for conducting demonstrations of technologies with the potential to reduce or eliminate the generation of hazardous wastes at Army industrial facilities. These demonstrations have been conducted to provide proof of the technical and economic feasibility of available and innovative technologies as well as to develop specific criteria necessary for implementation of the technologies throughout the Army.

The demonstrated technologies include:

- **Plastic Media Blasting** – reduces requirements for chemical paint stripping and use of non-reusable media
- **Particulate Filtration System** – extends chemical paint stripping bath lives by removing paint particulates
- **Electrodialysis Bath Purification System** – removes metal contaminants from chromic acid electroplating solutions and reforms chromic acid thereby extending the lives of these baths
- **Aluminum Ion Vapor Deposition** – deposits a coating of aluminum on parts to replace cadmium plating for corrosion resistance
- **Hot Gas Decontamination** – nondestructive means to decontaminate process equipment and structural components that have been contaminated with explosives and propellants
- **Use of Energetics as Supplemental Fuel** – reduces requirements for the open burning and controlled incineration of waste explosives and propellants.

To summarize the applicability of these technologies to Army implementation, a matrix has been prepared. This matrix (see figure) illustrates the response of each of the technologies to implementation-related characteristics such as:

- **State of Development** – addresses the current status of the technology. Has the technology been demonstrated in the field (FD) or is it available for full-scale implementation (FS)?
- **Army Operation Applicability** – describes the applicability of the technology to various Army operations including ammunition production; load, assemble, and pack; demilitarization; metal finishing; vehicle maintenance; and facility maintenance. These operations are representative of those conducted at a range of Army facilities including ammunition plants, depots, arsenals, munition testing facilities, and troop training facilities.
- **Type of Wastes Reduced** – describes the general types of wastes that may be reduced by implementation of the technology. These include paint wastes (P), solvent wastes (S), metal wastes (M), and energetic wastes (E).
- **Potential for Implementation** – describes the likely relative potential for implementation of the technology (low [L], medium [M], high [H]) based on the following factors:
 - user acceptability* (perception of users with regard to impact of the technology on productivity, product quality, health and safety, and ease of operation)
 - magnitude of waste reduction* (measure of incentive for implementation based on the potential for waste reduction)

- payback* (measure of incentive for implementation based on the potential for cost savings), and
- overall implementability* (indicative of the complexity of the system as well as the degree of facility modification and construction requirements).

In addition, brief summaries of each of the demonstrated technologies are provided. These summaries provide an introduction to the technical aspects of the technologies, an account of the demonstration(s) conducted, and a brief discussion of the implementation aspects and requirements for each technology. In addition, references and points of contact are provided for further information. These summaries are not intended to provide in-depth technical descriptions and discussions, but rather to be a first step to assessing the status and applicability of the technologies and a guide for obtaining additional information.

For Further Information

General information regarding waste reduction technology demonstrations and implementation can be obtained from:

**The U.S. Army Environmental Center
Process Development Branch
Aberdeen Proving Ground, Maryland
21010-5401**

(410) 671-2054

Accesion For	
NTIS	CRA&I <input checked="" type="checkbox"/>
DTIC	TAB <input checked="" type="checkbox"/>
Unannounced <input type="checkbox"/>	
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

Demonstrated Waste Reduction Technologies – Status, Applicability, and Implementation

Waste Reduction Technology	State of Development	Ammunition Production	Army Operation Applicability				Potential for Implementation					
			Load, Assemble, Pack	Demol.	Metal Finishing	Vehicle Maintenance	Facility Maintenance	Type of Waste Reduced	User	Waste Reduction	Payout	Implementation
Plastic Media Blasting	FS				X	X		P & S	M	H	M	H
Particulate Filtration System	FD				X	X		P & S	M	M	M	M
Electrolysis Bath Purification System	FD				X	X		M	H	H	H	H
Aluminum Ion Vapor Deposition	FS				X	X		M	H	H	M	M
Hot Gas Decontamination of Structures	FD	X	X	X			X	E	M	H	H	L
Hot Gas Decontamination of Equipment	FD	X	X	X			X	E	H	H	H	H
Use of Energetics as Supplemental Fuel	FD	X	X	X				E	M	H	M	L

KEY

FD - Field Demo

FS - Full-Scale

X - Applicable

L - Ranks Low
M - Ranks Medium
H - Ranks High

P - Paint Waste
S - Solvent Waste
M - Metal Waste
E - Energetic Waste

Source: Arthur D. Little, Inc.

Plastic Media Blasting

Description

Primary processes used in Army depot maintenance operations for paint removal include: chemical stripping, abrasive blasting, and hand sanding (used when other techniques can not be employed for practical reasons). Chemical stripping is used primarily for paint removal on small items where abrasive blasting is inefficient or for paint removal from substrates that would be damaged by conventional abrasive blasting (e.g., aluminum, copper, wood, and fiberglass composites). The most effective chemical strippers currently in use today include those containing a methylene chloride/formic acid formulation. The use of these chemical strippers is increasingly discouraged for health and disposal reasons.

Abrasive media used for paint removal include: sand and other mineral-based abrasives (e.g., peridot and garnet); steel grit and shot; glass beads; aluminum oxide; and walnut shells. Sand is a low cost media; however, the health hazards associated with dust inhalation have made it less attractive. Steel grit and shot are dense, aggressive media that effectively remove paint and corrosion. However, like other aggressive media, they can damage sensitive substrates and machined surfaces. Glass beads are typically not aggressive but have application for touch up work to clean and polish corroded surfaces. Walnut shells (and other agricultural media) are widely used as soft abrasive blast media for use on aluminum sheet and machined metal surfaces where minimum surface damage is required. These media are relatively low in cost - but are not durable. The use of these media also generate a fine dust that requires careful control to reduce operator inhalation and explosion potential.

Plastic media is a more recent abrasive media option. As a synthetic material (either thermoset or thermoplastic), the physical properties of plastic media can be controlled to a much greater extent than those of natural organic media to provide for improved durability, controlled hardness, and reduced dust generation. There is the potential that plastic media can replace more conventional chemical and abrasive stripping techniques and provide for: improved operating conditions from the aspects of operator

health and safety; decreased waste generation (and associated disposal costs) due to its ability to be recycled as well as the elimination of liquid wastes; and minimal damage to some sensitive substrates. Despite these potential benefits, it was recognized that testing and demonstration efforts would be required to identify the specific applicability of plastic media to remove paint from actual parts in Army maintenance operations.

The first full-scale plastic media blasting (PMB) operation was implemented in 1985 at Hill Air Force Base (Ogden, Utah) to depaint aircraft - the primary application of PMB. In such applications, PMB has reduced environmental, health, and safety problems associated with chemical stripping. In addition, the use of PMB on aircraft has been cost effective (over chemical stripping) due to reduced material costs, waste disposal costs, and labor requirements. However, the potential for substrate damage posed by abrasive blasting continues to be a concern.

Demonstration

To assess the applicability of PMB on non-aircraft Army equipment undergoing maintenance (depainting, corrosion removal, and surface preparation), a demonstration program was conducted from December 1987 through October 1988 at Letterkenny Army Depot (LEAD) in Chambersburg, Pennsylvania. This demonstration program consisted of four series of tests: three test series were performed in a blast cabinet, the final series was performed in a new walk-in blast booth purchased and installed for the demonstration program . The walk-in booth was retained for depot use after completion of the demonstration program.

Equipment parts that were subjected to PMB included aluminum and steel parts of various sizes and thicknesses representing a range of materiel currently being depainted at Army depots. In addition, parts consisting of fiberglass, brass, and copper were evaluated. Small parts investigated in the blast cabinet included over 40 different types such as smoke generator toolboxes, smoke generator fog oil pump parts, and

engine parts. Larger parts were subjected to PMB in the walk-in booth. These parts included: containers, electronic shelters, artillery shells, and chemical agent decontamination units.

The demonstration program was designed to meet a number of objectives including:

- Determine and compare paint removal and media consumption rates of several types and sizes of commercially-available plastic media.
- Determine and compare paint removal and media consumption rates of walnut shells and glass beads to those rates established for PMB.
- Determine the optimum blast parameters for PMB (e.g., media flow rates, blast stand-off distances, and blast pressures).
- Determine the applicability of PMB on Army equipment parts of various shapes, sizes, and materials of construction.
- Determine the applicability of PMB to remove Chemical Agent Resistant Coating (CARC) paint systems.

Demonstration Results

Results of the demonstration program reflected the following:

- PMB effectively removed conventional paint coatings on all shapes, sizes, and materials of construction tested.
- In blast cabinet tests, it was shown that under optimum blast pressures, PMB generated an average of 70% less waste than glass beads and 40% less waste than walnut shells. The average paint removal rate achieved with walnut shells was 40% higher than that of plastic media or glass beads.
- In walk-in booth tests, PMB exhibited similar paint removal rates to walnut shell blasting at optimum blast pressures for each. At these conditions, PMB resulted in the generation of 50% less waste than walnut shell blasting. A combination of plastic media and glass beads reduced paint removal rates by approximately 30%; however, this combination of media was more effective in removing surface rust and corrosion than either walnut shells or plastic media alone.
- In walk-in booth tests, plastic media, walnut shells, and the plastic media/glass bead combination were

effective in removing CARC.

- PMB was effective in surface preparation involving cleaning and roughening of surfaces to ensure adequate paint adhesion.
- Under optimum operating conditions, PMB was effective at removing paint and not delaminating, warping, or pitting delicate substrates such as thin aluminum, fiberglass, brass, and copper.
- Optimum blast conditions for the blast cabinet were identified as: 30 to 40 psi blast pressure; 6 to 10-inch blast stand-off distance; and 4 to 5 lb/min media flow rate.
- Optimum blast conditions for the walk-in booth were identified as: 40 psi blast pressure; 18 to 30-inch blast stand-off distance; and 6 to 9 lb/min media flow rate.
- An economic comparison of depainting methods for small parts indicated that chemical stripping was the least expensive depainting method followed by walnut shell, glass bead, and plastic media blasting, respectively. Labor requirements are significantly higher for abrasive blasting than for chemical stripping. The use of automated blast equipment has the potential to reduce labor costs. It is expected that as waste disposal costs increase, the economics of abrasive blasting in general become more attractive. Further, given higher waste disposal costs, the economics of PMB are enhanced due to lower waste generation rates.
- An economic comparison of abrasive blasting techniques for large equipment parts indicated that walnut shell blasting was less expensive than either PMB or blasting with the plastic media/glass bead combination. The increased cost was primarily due to the higher cost of plastic media.

Implementation

The implementability of plastic media blasting varies across the Army depots depending primarily on the type of parts to be maintained. The primary applications for PMB within the Army thus far have been to strip paint from aluminum parts such as aircraft parts and communication shelters. In addition to the full-scale PMB booth installed at Letterkenny Army Depot for the demonstration program described above, PMB booths have been installed at Corpus Christi (Texas) Army Depot and Sacramento (California) Army Depot. The Army National Guard Bureau has se-

lected PMB for installation at four of its facilities (Mississippi, Connecticut, Missouri, and California) to supplement chemical paint stripping operations for aircraft and ground mobile vehicles. The PMB system at the Mississippi Army Reserve National Guard facility is currently in operation.

PMB is in use at a number of Air Force and Navy activities with further applications planned. Second generation PMB blast booths (incorporating increased automation) have been installed at Hill Air Force Base.

References

Arthur D. Little, Inc., *Implementation of Plastic Media Blasting (PMB) at U.S. Army Depots*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. AMXTH-TE-CR-87120, January 1988.

Arthur D. Little, Inc., *Demonstration Testing of Plastic Media Blasting (PMB) at Letterkenny Army Depot*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TE-CR-89004, January 1989.

Point of Contact

Ronald Jackson, U.S. Army Environmental Center,
(410) 671-1562.

Paint Stripper Filtration

Description

Strong alkaline paint stripping solutions are used to remove metal-based paints from metal parts at Army depots. As paint is removed from the parts, a sludge is generated that is suspended and settled within the stripping bath. The components of this sludge continue to react with the alkaline stripper thereby prematurely exhausting the useful capacity of the stripper. In addition, the sludge contributes to an increase in the contamination and solids content of drag-out as parts are removed from the stripper bath for rinsing.

Typically, sludges in the stripping tanks are removed only when the bath is replaced and therefore contribute to the depletion of the stripping components as well as increase the contamination of rinse waters throughout the life of the tank. In order to investigate the potential for extending the lives of these strippers (as well as reducing the amount of contamination in rinsewaters), a demonstration of a process to continuously remove paint sludges from the baths was conducted.

There are many technologies that have potential application for the removal of paint solids from stripper baths including:

- pressure filtration (bag)
- centrifugation
- gravity belt filtration
- vacuum filtration
- hydrocyclone
- microfiltration
- sedimentation
- skimmers

Of the technologies considered, pressure filtration using filter bags was selected due to the capability of the system for rapid filtration of typically difficult separations. Additional attractive features of pressure filtration include a relatively low capital cost and increased flexibility in operation offered by the ability to change filters to accomodate the removal of solids with different particle sizes.

In the filtration system, the alkaline paint stripping solution is pumped from one end of the tank containing the bath, pumped through the pressure filter, and returned to the opposite end of the tank with agitation. Multiple filters may be used in series or in parallel. Filter bags with varying pore sizes may be used to achieve adequate filtration as conditions in the bath change.

Demonstration

To assess the effectiveness of the pressure filtration system in removing particulates from the alkaline stripper baths, a field demonstration/testing program was conducted from late 1990 to early 1991 at Letterkenny Army Depot (LEAD) in Chambersburg, Pennsylvania.

The filtration system, as described above, was designed and constructed especially for application at LEAD in a 3300 gallon open-topped alkaline stripping tank (normally operated with approximately 2500 gallons of solution). The alkaline solution consists of water, sodium hydroxide, sodium gluconate, and other compounds in trace amounts.

The filtration system consisted of three filtration units in series capable of operating at 150 psig. A progressive cavity pump was selected to transport the solution through the filtration system. Design criteria for the pump included a flow of 50 gallons per minute at a maximum total system pressure drop of 125 psi. Controls were applied to shut down pump operation in case of high pressure (due to plugging of the filtration system downstream of the pump) or low pressure (plugging upstream or empty tank). A mixing eductor was installed on the filtration system return line to provide for agitation of the alkaline stripping solution thus assuring that sludges and solids are able to be moved toward the suction pipe.

Once installed, the filtration system began operation and the following data were monitored and/or collected:

- parts placed into the alkaline paint stripper bath

- chemicals added to the alkaline paint stripper bath
- alkaline paint stripper bath temperature
- standard quality control testing of the solution (including solids content, settling time, specific gravity, alkalinity, and particle size distribution) performed by the in-house laboratory
- replacement frequency of bag filters
- characteristics of used filter bags

Upon completion of the field demonstration, the system was left in place for ongoing use and process optimization by LEAD personnel.

Demonstration Results

Based on initial results, two operational modes were developed to provide for: 1) continuous removal of suspended solids; and 2) periodic removal of settled sludge. The former mode was successfully demonstrated by using three successive filter bags including: a 400 µm bag in the first filter housing; a 200 µm bag in the second housing; and a 50 µm bag in the third housing. The bags required replacement midway through a week of operation when the filtration system was operated for two 8-hour shifts a day.

In the event a sludge layer accumulates in the tank during filtration downtime periods or when it is desired to reclaim contaminated stripping baths, the second operational mode provides for the removal of the sludge from the tank without emptying the tank. In this mode, the sludge was raked within the tank to move it to the suction line. Only the first filter equipped with a 400 µm filter bag was used. Once blinded (as indicated by a pressure drop in the system), the system was shut down, the bag was removed and emptied, and the cycle was repeated as necessary.

By operating the filtration system in one of the operational modes described above, it was demonstrated that the pressure filtration system was capable of removing solids from the alkaline paint stripper bath.

Implementation

The results of the field demonstration indicated that the filtration system would have potential application in the extension of alkaline paint stripping bath lives by successfully removing paint sludges and solids

from the tank. Optimum operation of the filtration system with alkaline paint stripping baths may be achieved by:

- starting the filtration process with a clean bath to allow for the removal of particulates as they are generated
- shutting down the filtration system periodically (once per week, for example) and for cleaning and bag replacement
- using a filter train employing filter bags with 400, 100, and 50 µm pore sizes

There is potential for application of the paint stripper filtration system with other types of chemical strippers (methylene chloride-based, for example). Other applications will require field investigations to identify optimum operating conditions. For further information about implementation of the process, contact the U.S. Army Environmental Center (point of contact provided below).

References

Mathis, J. and J.S. Davis, *Evaluation of a Particulate Filtration System for an Alkaline Paint Stripper at Letterkenny Army Depot*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TS-CR-91033, August 1991.

Point of Contact

Ronald Jackson, U.S. Army Environmental Center, (410) 671-1562.

Electrodialysis of Chromic Acid Solutions

Description

During metal pretreatment and finishing operations at Army depots, a variety of process solutions that contain chromic acid are used. Operations that employ chromic acid solutions include: functional (hard) chromium electroplating; application of chromate conversion coatings on aluminum, cadmium, steel, and magnesium; removal of chromate conversion coatings; and anodizing. As these solutions are used, they become contaminated with metals and other impurities. Metal contamination may be a result of carryover from other process or rinse tanks or may be caused by actual dissolution of metals that come into contact with the solution. The most common impurity in chromic acid solutions is trivalent chromium generated when hexavalent chromium (the form of chromium in chromic acid) is reduced.

The presence of impurities in the chromic acid solutions cause a number of problems including:

- a reduction in removal rate of older conversion coatings as well as a diminishing of the quality of the cleaned parts
- plating quality problems in addition to decrease in bath conductivity and plating efficiency
- a need for frequent disposal of the process solutions as they become exhausted

In order to extend the lives of chromic acid solutions, an innovative technology was investigated with the potential to remove the impurities from the solution. This technology makes use of a specialized configuration of conventional electrodialysis technology.

In this process, the chromic acid solution is passed through an electrodialysis cell consisting of an anode immersed in an anolyte solution (i.e., chromic acid process solution), a cathode immersed in a catholyte solution (a caustic solution), and a cation-permeable membrane separating the two solutions. When voltage is applied, the positive charge created at the anode drives the cations through the membrane. Trivalent chromium may be oxidized to hexavalent chromium in the anolyte or it may be passed through the membrane with the other cations. Electrolysis of

water occurs at the anode to generate oxygen gas and hydrogen cations that can combine with chromate anions and thereby regenerate the chromic acid.

In the caustic catholyte, cations will react with hydroxyl ions to form insoluble hydroxides that precipitate (in contrast with standard electrodialysis units in which the metals plate out on the cathode). The metal precipitates form a sludge that can be filtered from the solution. Electrodialysis using a caustic catholyte as described allows for the removal of metal contaminants from the chromium acid solution while reforming chromic acid. As a result, this process should result in longer bath life, a less variable chromic acid concentration, reduced requirements for chromic acid makeup, and decreased generation of hazardous waste.

Demonstration

A demonstration of the use of a patented technology employing the electrodialysis process described above was conducted at Corpus Christi (Texas) Army Depot from September 1990 to April 1991.

The objective of the demonstration program was to evaluate the ability of the commercially-available electrodialysis system to recover and purify representative contaminated chromic acid solutions. As such, the electrodialysis process was employed for use in rejuvenating two full-scale chromic acid solutions: 1) a chromic acid stripping solution used to removing chromate conversion coatings from magnesium transmission parts; and 2) a hard chromium electroplating bath.

Among the parameters planned for evaluation in these field tests were:

- rate of contaminant metal removal
- capability of system in oxidizing trivalent to hexavalent chromium
- identification of metals that are successfully precipitated as hydroxides
- applicability of rejuvenated solution for reuse

- identification of disposal methods for the spent catholyte solution.

Demonstration Results

In full-scale testing of the rejuvenation of a chromic acid stripping solution, the electrodialysis system was proven successful in removing a significant quantity of metal impurities from the chromic acid solution. These demonstrations were complicated by the presence of a hole in the electrodialytic membrane that caused sulfate contamination of the chromic acid solution resulting in the damage of parts being processed. Subsequent bench-scale tests demonstrated that these sulfates could be precipitated by barium carbonate. Because of the potential for contamination of the chromic acid solution with sulfates, operation of the electrodialysis cell in-line with an operating stripping solution is not recommended. An alternative configuration may consist of using the cell in a separate holding tank containing the spent stripping solution, adding barium carbonate to precipitate any sulfate that may be present, and returning the rejuvenated solution to the stripping tank.

Demonstration of the electrodialysis process with a hard chromium electroplating solution proved that the process was capable of significantly reducing concentration of metal contaminants (including trivalent chromium). Longer-term operation and monitoring (than was possible in the scope of this demonstration) is required to identify and verify the potential benefits of the system including: hazardous waste reduction; reduction in rejection of part rejects; reduction of sludge buildup; and an increase in plating efficiency.

Implementation

The results of the field demonstrations indicated that the electrodialysis of chromic acid process solutions has potential for successfully removing metal impurities from the solutions thereby allowing for an increase in the lives of the baths as well as improving the performance of the solutions.

As observed in the demonstrations, due to the potential for membrane leakage, it is recommended that process solutions that are sensitive to the presence of sulfates (i.e., chromic acid stripping solutions) be

treated off-line to ensure that sulfates are not introduced into the stripping baths.

For further information regarding this demonstration refer to the reference below. For further information and/or assistance in implementation of the process, contact the U.S. Army Environmental Center (point of contact provided below).

References

Davis, J. S., *Evaluation of Electrodialysis for Chromic Acid Recovery and Purification at Corpus Christi Army Depot*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TS-CR-91032, September 1991.

Point of Contact

Ronald Jackson, U.S. Army Environmental Center, (410) 671-1562.

Aluminum Ion Vapor Deposition

Description

In Army maintenance operations, electroplating of metal parts with cadmium is performed to provide the parts with a coating that provides for: good corrosion resistance (especially in saltwater environments); a good base for soldering; and a low coefficient of friction that allows for threaded connections to be made with a minimum of torque. Despite the benefits of a cadmium coating, cadmium plating generates significant quantities of a variety of wastes such as cadmium- and cyanide-bearing sludges, rinse waters, and spent plating solutions. As a toxic, carcinogenic metal, the presence of cadmium in these wastes results in these wastes being characterized as hazardous with attendant requirements for management and disposal. In addition, special care must be taken to protect worker health by reducing the potential for exposure to cadmium-containing solutions and wastes.

As an alternative to the use of cadmium plating, the application of an aluminum coating by ion vapor deposition is being examined. This process results in the application of a thin aluminum coating on metal parts to provide for a protective coating. The aluminum ion vapor deposition (AIVD) process does not generate hazardous wastes (however, a small volume of caustic waste is generated during periodic cleaning of the unit and its components). As a result, there is great potential for the process to reduce the amount of hazardous wastes generated during plating operations. In addition, the replacement of cadmium with aluminum reduces the potential risks and hazards to worker health.

The AIVD process is based on the deposition of positively charged aluminum ions onto a clean, negatively charged, metal surface. The process takes place in an enclosed chamber. Once parts are placed into the chamber, the chamber is evacuated to reduce the air pressure to a maximum of 6×10^{-3} torr. Argon gas is then introduced to raise the pressure to about 6×10^{-3} torr. A high voltage discharge is used to ionize some of the argon to produce positive ions that bombard the negatively charged metal surface and provide final cleaning.

After the argon cleaning, pure aluminum wire is fed into ceramic, electrical-resistance heaters ("boats"), where the wire is melted and vaporized. The boats move through the chamber to provide even distribution of the aluminum. The aluminum vapor is ionized by transfer of a positive charge from the argon ions. Aluminum ions are then attracted to the metal surface and deposited as a thin metal film.

Over 70 AIVD systems are in current operation in commercial and military activities. Most of the applications involve the plating of aircraft parts with a pure aluminum coating laid over an aluminum alloy substrate to provide corrosion protection.

Demonstration

To evaluate the potential for the AIVD process to replace cadmium plating in Army maintenance operations, a full-scale AIVD production unit was purchased, installed, and demonstrated at Anniston (Alabama) Army Depot (ANAD). This demonstration took place from October 1990 to April 1991.

In addition to determining the viability of AIVD to replace cadmium plating, a secondary objective of the demonstration was to develop the operating skills of the ANAD AIVD operators. The demonstration was designed to establish operating parameters such as wire feed rate and boat speed in order to achieve reproducible coatings that satisfy specifications regarding coating thickness, adherence, corrosion protection, and appearance.

The demonstration consisted of the deposition of aluminum on 86 parts used on Army vehicles and engines. Additionally, numerous nuts, bolts, brackets, and other small parts were plated using a barrel coater.

Demonstration Results

The results of the demonstration indicated that AIVD coatings were equal, or superior, to cadmium coatings on the parts tested. It was determined that, in most

cases, AIVD could be substituted directly for cadmium plating and would require minimal changes in requirements for pretreatment or posttreatment procedures for parts. Pretreatment of parts with selded surfaces and recessed areas may require modification to include preheating to eliminate outgassing from trapped moisture. Posttreatment changes would include lubrication of aluminum coated threaded parts prior to assembly as well as separation from cadmium-plated fasteners, particularly for parts with critical torque requirements.

Additional findings of the demonstration included identification of parts with recesses where the recesses could not be coated with aluminum by AIVD. These parts are typically those with recesses more than one diameter deep (two diameters deep if the part is open at both ends). If coating of the interiors of these recesses is required, alternative coatings would be required.

As a result of the demonstration, ANAD personnel have identified approximately 450 vehicle and engine parts that are suitable for aluminum platings in lieu of cadmium electroplates. Approval of these substitutions has been requested.

Implementation

Although the capital cost of the AIVD system is high (approximately \$1,025,000 in 1991 - compared to \$600,000 for an equivalent cadmium plating system), the potential for waste reduction is significant. For example, it is estimated that replacing cadmium plating with AIVD at ANAD would result in the reduction of about 15,000 pounds of hazardous wastes and 250,000 gallons of wastewater annually. As the AIVD technology matures, and as regulations regarding the operation of cadmium plating lines and the management of the wastes they generate become more stringent, the comparative cost of AIVD coatings should decrease over time.

The use of AIVD coatings continues to increase in industry and in government. As a result of the successful demonstration of AIVD, ANAD personnel have procured and installed an additional full-scale AIVD unit. In addition, an AIVD system has been recently been installed at Corpus Christi (Texas)

Army Depot for the application of aluminum to steel parts.

For additional information regarding the ANAD demonstration, refer to the reference below. For further information and/or assistance in implementation of the process, contact the U.S. Army Environmental Center (point of contact provided below).

References

Ressl, R., and J. Spessard, *Evaluation of Aluminum Ion Vapor Deposition as a Replacement for Cadmium Electroplating at Anniston Army Depot*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TS-CR-91054, April 1992.

Point of Contact

Ronald Jackson, U.S. Army Environmental Center, (410) 671-1562.

Decontamination of Explosives-Contaminated Structures and Equipment

Description

The manufacture and handling of explosives and propellants by the Army has resulted in the contamination of a wide variety of materials at Army installations. These materials include process equipment (e.g., piping, pumps, motors, etc.), underground sewer pipes, and structural components. Because these materials are contaminated, they often can not be reused or disposed of as scrap and therefore represent a significant source of hazardous waste.

In order to increase the potential for reuse or safe disposal of these contaminated materials, nondestructive decontamination techniques were identified and evaluated. Such techniques included solvent vapor condensation, solvent extraction, chemical reaction, and hot gas treatment. Of the techniques evaluated, the use of hot gas was shown to be the best potential alternative and was subjected to demonstration-scale testing.

The hot gas technique employs burners to heat air to temperatures in the range of 500 to 1500°F. The contaminated materials are exposed to the hot gas in a controlled environment to allow for the volatilization and partial destruction of contaminants. The contaminated gases are then passed to an afterburner to complete the destruction of contaminants.

Similar thermal techniques have been used at Army ammunition plants to provide for decontamination of items internal to their operations. The results of these thermal decontamination operations have not been documented and their effectiveness has not been demonstrated. The demonstration program conducted by the U.S. Army Environmental Center will provide for the generation of data and information necessary for the safe and effective implementation of the hot gas decontamination process at Army installations.

Demonstration

To evaluate the potential for the hot gas process to decontaminate explosive-contaminated equipment and structural materials, two demonstrations were performed. The first of these was conducted at Cornhusker Army Ammunition Plant (CHAAP), Nebraska in 1987. This demonstration involved the use of hot gas to heat the explosive-contaminated concrete block interior of a small building (approximately 22 feet by 24 feet) to a temperature of approximately 500°F. Contaminant-laden off gases were passed through a thermal oxidizer (afterburner) located outside the building to destroy the contaminants prior to discharge of the gases to the atmosphere. The objectives of this demonstration were to determine the effectiveness of hot gas decontamination as well as to identify the impact, if any, of the hot gas on the structural integrity of the concrete materials.

The second demonstration of the hot gas decontamination process was conducted at Hawthorne Army Ammunition Plant (HWAAP), Nevada in 1989-1990. The primary objective of this demonstration was to determine the effectiveness and optimum operating conditions of the hot gas system to decontaminate explosive and propellant-contaminated equipment (aluminum and steel) and masonry sewer pipe. This demonstration employed an air preheater, flash chamber, and afterburner to decontaminate equipment under a range of temperatures (400, 500, and 600°F) and residence times (6, 12, 24, 36, and 48 hours). Contaminants included TNT, smokeless powder, and ammonium picrate.

Further demonstration of the hot gas decontamination process is planned for the summer of 1994 at HWAAP.

Demonstration Results

The primary results of the first demonstration of the hot gas decontamination process at CHAAP indicated the following:

- The concentration of TNT on the surface of the concrete block was typically reduced by 99.9% or greater (to approximately 1 µg/sq cm of surface area).
- The concentration of TNT within the concrete block was typically reduced by 90 to 99.9% or greater (to levels at or below 0.11 µg/g of concrete material).
- An acceptable level of loss of structural strength of the concrete block was observed under operating conditions involving a moderate heat-up rate (5% loss in compressive strength and 20 to 30% loss in tensile strength).

The decontamination of explosive and propellant-contaminated equipment and sewer pipe at HWAAP indicated that the hot gas process is effective for treating items contaminated with TNT and ammonium picrate. Some of the specific findings included:

- TNT-contaminated items that were treated for 6 hours at a minimum temperature of 500°F were not characteristically hazardous and may be appropriate for disposal or sale as scrap.
- Items with contamination on external surfaces were more easily decontaminated than items with complex geometries with contamination on internal surfaces.
- Items constructed of steel or aluminum appeared to be undamaged by the hot gas treatment. Hot gas treatment of masonry items, however, resulted in embrittlement and cracking.

The results of both of the demonstrations have indicated the feasibility of using hot gas to decontaminated equipment and structural items and have provided information to further the technology on toward implementation.

Implementation

Although the two demonstrations of hot gas decontamination conducted by the Army have indicated the promise of the technology, additional demonstrations are planned for 1994. These demonstrations will serve to expand the data base to meet safety and quality assurance/quality control needs as well as to allow for the design of a generic hot gas decontamination system with supporting economic analysis.

The 1994 demonstrations will be conducted at the Western Area Demilitarization Facility (WADF) at HWAAP. The demonstrations will be designed specifically to address decontamination requirements of WADF demilitarization operations. As such, the results will be used to permit HWAAP to put the system into full-scale operation at the WADF.

For additional information regarding the two completed demonstrations of the hot gas decontamination process, refer to the references listed below. For further information about the 1994 demonstrations and plans for implementation, contact the U.S. Army Environmental Center (point of contact provided below).

References

Woodland, L.R., et al., *Pilot Plant Testing of Caustic Spray/Hot Gas Building Decontamination Process*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. AMXTH-TE-CR-87112, August 1987.

Mazelon, Mike, et al., *Pilot Test of Hot Gas Decontamination of Explosives-Contaminated Equipment at Hawthorne Army Ammunition Plant (HWAAP)*, Hawthorne, Nevada, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TE-CR-90036, July 1990.

Point of Contact

Erik B. Hangeland, U.S. Army Environmental Center, (410) 671-2054.

Waste Energetics as Supplemental Fuel

Description

The Army generates and stores significant quantities of energetic materials that do not meet specifications for their primary use. Current methods of disposal of these energetic materials include open burning/open detonation (OB/OD) and incineration. OB/OD, although inexpensive to conduct, is increasingly becoming more and more restricted due to the potential for undesirable environmental consequences.

For safety reasons, incineration of waste energetic materials is conducted by burning the wastes in a water slurry with a water to energetic ratio of three to one (on a weight basis). Because of the excess water, additional fuel is required to incinerate the energetics and the resulting costs are high.

In 1985, the Army undertook an effort to develop an alternative means of managing these wastes. A testing program was initiated to evaluate the potential for cofiring the energetics with fuel oil to generate steam or electricity. Such a process would allow for the recovery of the energy content of the energetics as well as provide an environmentally acceptable means of managing the wastes. Initially, the program was oriented toward the explosives TNT, RDX, and Composition B (a mixture of TNT and RDX) since these explosives comprise the largest portion of the waste energetics.

In the cofiring process, the explosives would first be mixed with toluene to dissolve the TNT and break down the insoluble RDX into the smaller particle sizes required for the use of existing burner technology. Initial testing concentrated on an evaluation of the various operational and safety criteria relevant to cofiring explosives with fuel oil. A series of bench-scale tests were conducted to evaluate the chemical stability, handling characteristics, and reactivity of the various explosive, solvent, and fuel oil mixtures. The results of these tests indicated that the various mixtures were chemically compatible and could be handled safely. Results of explosive propagation tests identified the maximum allowable concentrations of explosives that could be transported in process piping without propagation of detonation. The maximum

allowable concentration of RDX (the most sensitive of the explosives tested) was established at 15% (by weight in fuel oil).

Additional analyses were conducted to evaluate the feasibility of using waste propellants as fuel supplements. These analyses included laboratory tests to determine the chemical and physical characteristics of propellant and fuel oil slurries, the chemical compatibility of the mixtures, and explosive propagation characteristics. In addition an economic analysis was performed. Preliminary results of these analyses indicate that using the waste propellants as a fuel supplement is technically feasible and may offer some cost benefit over existing methods of thermal destruction of the wastes. Further evaluation will be required to identify appropriate oil burners capable of burning the viscous slurries.

Demonstration

In 1987, a "proof-of-principle" pilot-scale test of the explosive/fuel oil cofiring process was conducted at Los Alamos National Laboratory. A one million BTU/hr trial combustor was operated using fuel oil supplemented with TNT, RDX, and Composition B. Although this demonstration was discontinued prematurely due to equipment failure, adequate operational experience and data were obtained to demonstrate that explosives could be safely cofired with fuel oil.

Lessons learned from the 1987 demonstration were used in the design and construction of a state-of-the-art pilot-scale cofiring system. This system, constructed in 1989, includes the following features: solvent storage capability; a system to mix and heat the solvents and explosives; a blending system to mix the explosive/solvent mixture with fuel oil; a standard industrial water tube boiler equipped to fire fuel oil and/or an explosives/fuel oil slurry; and a system to control and modulate the flow of steam generated by the boiler.

A demonstration of the use of this state-of-the-art system was conducted in 1990 at Hawthorne Army Ammunition Plant (HWAAP), Nevada. Initially,

three tests were conducted with fuel oil only to provide a baseline with respect to boiler combustion characteristics (i.e., combustion efficiencies and emissions). Subsequent to establishing the baseline, two tests were conducted using mixtures of 1% and 15% TNT in toluene and fuel oil.

Demonstration Results

The results of the HWAAP demonstration indicated that dilute concentrations of TNT can be fired effectively in the boiler. It was shown that combustion characteristics and boiler efficiency were not greatly affected by the presence of explosives. Analysis of the final results indicated that the destruction ratio efficiency (DRE) for TNT was greater than 99.99%.

Despite the favorable results, there were some concerns regarding the difficulties experienced in completely dissolving the TNT in fuel oil and toluene and keeping the TNT in solution once dissolved. These problems create safety concerns in the event that TNT settles in process parts and piping. To address these problems, process modifications were identified to enhance TNT dissolution and resolve handling problems from safety and processing standpoints. The recommended process modifications were completed and will be demonstrated in the next phase of testing (see below).

Implementation

Further development of the supplemental fuel system will be completed as part of a joint effort between the Army and the Navy. The modified supplemental fuel system used at HWAAP has been moved to the Naval Ordnance Station, Indian Head, Maryland and will be subjected to a joint service demonstration in 1994. The results of this demonstration will be used to develop full-scale operational and safety criteria for implementation.

For additional information regarding the evaluation, testing, and demonstration activities described above, refer to the references below. For further information regarding future demonstrations and implementation, contact the U.S. Army Environmental Center (point of contact provided below).

References

Lackey, M.E., *Testing to Determine Chemical Stability, Handling Characteristics, and Reactivity of Energetic-Fuel Mixtures*, Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. AMXTH-TE-CR-87132, April 1988.

Bradshaw, W.M., *Pilot-Scale Testing of a Fuel Oil-Explosives Cofiring process for Recovering Energy from Waste Explosives*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. AMXTH-TE-CR-88272, May 1988.

Cosmos, M. and P. Marks, *Pilot Test to Determine the Feasibility of Using Explosives as Supplemental Fuel at Hawthorne Army Ammunition Plant (HWAAP)* Hawthorne, Nevada, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TE-CR-91006, April 1991.

Norwood, V.M., et al., *Technical and Economic Analyses to Assess the Feasibility of Using Propellant-No. 2 Fuel Oil Slurries as Supplemental Fuels*, Final Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TS-CR-91046, September 1991.

Norwood, V.M. and D.J. Craft, *Zero Gap Propagation Testing of Propellant-No. 2 Fuel Oil Slurries*, Report to the U.S. Army Toxic and Hazardous Materials Agency, Report No. CETHA-TS-CR-92005, January 1992.

Point of Contact

Louis Kanaris, U.S. Army Environmental Center, (410) 671-1558.